# Hypervelocity Impact Performance of Open Cell Foam Core Sandwich Panel Structures

S. Ryan[1], E. Christiansen[3]

[1] USRA Lunar and Planetary Institute, Houston
[2] National Aeronautics and Space Administration (NASA), Houston

Metallic foams are a relatively new class of materials with low density and novel physical, mechanical, thermal, electrical and acoustic properties. Although incompletely characterized, they offer comparable mechanical performance to traditional spacecraft structural materials (i.e. honeycomb sandwich panels) without detrimental through-thickness channeling cells. There are two competing types of metallic foams: open cell and closed cell. Open cell foams are considered the more promising technology due to their lower weight and higher degree of homogeneity.

Leading micrometeoroid and orbital debris shields (MMOD) incorporate thin plates separated by a void space (i.e. Whipple shield). Inclusion of intermediate fabric layers, or multiple bumper plates have led to significant performance enhancements, yet these shields require additional non-ballistic mass for installation (fasteners, supports, etc.) that can consume up to 35% of the total shield weight [1]. Structural panels, such as open cell foam core sandwich panels, that are also capable of providing sufficient MMOD protection, represent a significant potential for increased efficiency in hypervelocity impact shielding from a systems perspective through a reduction in required non-ballistic mass.

In this paper, the results of an extensive impact test program on aluminum foam core sandwich panels are reported. The effect of pore density, and core thickness on shielding performance have been evaluated over impact velocities ranging from 2.2 – 9.3 km/s at various angles. A number of additional tests on alternate sandwich panel configurations of comparable-weight have also been performed, including aluminum honeycomb sandwich panels (see Figure 1), Nomex honeycomb core sandwich panels, and 3D aluminum honeycomb sandwich panels. A total of 70 hypervelocity impact tests are reported, from which an empirical ballistic limit equation (BLE) has been derived. The BLE is in the standard form suitable for implementation in risk analysis software, and includes the effect of panel thickness, core density, and facesheet material properties. A comparison between the shielding performance of foam core sandwich panel structures and common MMOD shielding configurations is made for both conservative (additional 35% non-ballistic mass) and optimistic (additional mass equal to 30% of bumper mass) considerations. Suggestions to improve the shielding performance of foam core sandwich panels are made, including the use of outer mesh layers, intermediate fabric/composite layers, and varying pore density.

**References:**

[1] R. Destefanis, F.K. Schaefer, M. Lambert, M. Faraud, E. Schneider, "*Enhanced Space Debris Shields for Manned Spacecraft*", International Journal of Impact Engineering; 29: 215-226, 2003.

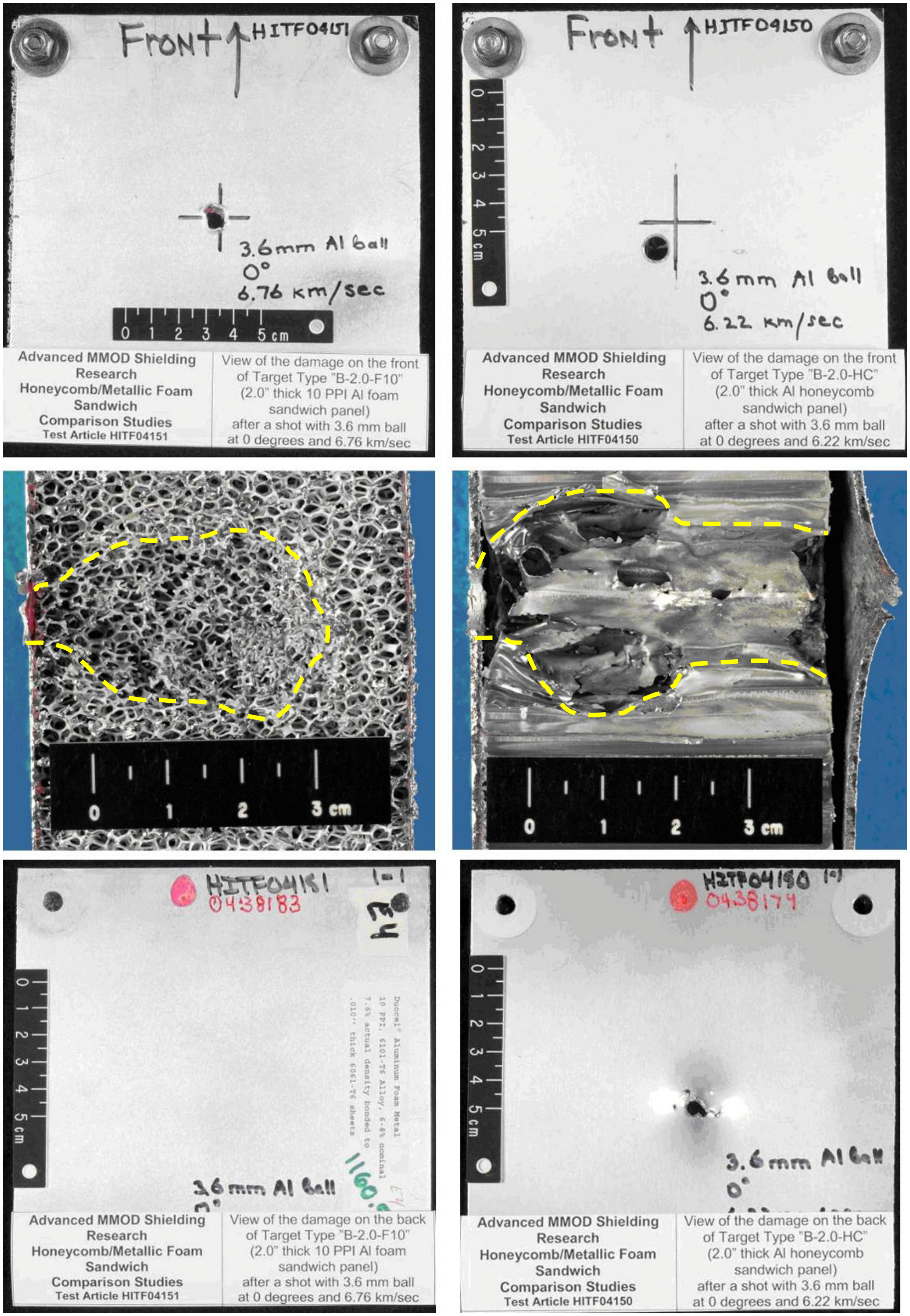


**Figure 1: Comparison of damages in an open cell foam core (left) and honeycomb core (right) sandwich panel structures impacted by a 3.6 mm Al-sphere at 6.49±0.27 km/s (0°).**